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GAMMA BURSTS

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Gamma bursts are now universally accepted as having an origin associated with neutron stars. The intensity inferred for an origin local to our region of the Milky Way is then close to the Eddington limit for a solar mass. The distribution and intensity versus number, the log N log S curve then allows for the large departures from slope 3/2 considered by Jennings and Jennings and White.[1,2] The probable identification of the location of one event by Schaefer[3] further suggests a local original within the galaxy and hence neutron stars. The difficulty with any simplistic mechanism for the production of gamma bursts in the vicinity of a neutron star is the extreme nonthermal character of the spectrum[4,5] and the large thickness associated with a gravitational energy release on the neutron star. The gravitational binding is the of the order of 1/10 to 2/10 of the rest matter reaching a neutron star surface, which would seem to be a likely maximum specific energy density source for a gamma burst. Since the resulting thickness for compton scattering is $\tau \sim 10^5$, the mechanism for producing a thin spectrum, high temperature radiation is still obscure. Somehow or other the radiation must find its way around the matter that is releasing the energy. This same argument is exaggerated 100-fold if the energy source is thermonuclear, because the specific energy density released is 100 times smaller per gram of matter. Explanations of gamma burst spectra that are made independent of the thickness of the radiating matter suffer because of this one major difficulty.

The March 5 event is singular in many aspects but particularly the spectrum is softer by a factor of 3. The spectrum is soft enough such that it is reasonable to model the radiation emitted as being black body and further a black body temperature associated with either accretion or a thermonuclear origin. The fact that the black body radiation flux even for this softer spectrum would vastly exceed the Eddington limit for gravitational stress can be circumvented by the constraint of a strong magnetic field.[6] The same strong field, however, absolutely insures a black body spectrum of emitted photons.

Radiation Thermalization in Magnetic Fields

A high-temperature plasma and a strong magnetic field emits harmonics of the cyclotron frequency.[7] The field strength necessary to confine the high temperature plasma is $\gtrsim 10^{10}$ gauss when the plasma is radiating at the black body limit associated with a characteristic temperature of the March 5 event, kT ~ 20 keV. Then the effective photon emission mean-free path is a small fraction ~ 2×10^{-3} of a compton scattering mean free path. Therefore the emission and absorption of higher harmonics of cyclotron emission, rapidly thermalizes the radiation field so that compton scattering cannot be invoked to produce a large nonthermal component. As a consequence, we see no way to consistently use a magnetic field to confine a high temperature plasma and at the same time emit a highly nonthermal spectra characteristic of the average gamma burst.

Spectral Mechanisms

A classical modeling of the high temperature nonthermal gamma burst spectrum has been as Bremsstrahlung[4] and more recently as comptonized black body radiation.[5] A problem with both of these mechanisms is a combination of the thinness of the required emission region and then the resulting necessary nonthermal heating of the electrons leading to the respective emissions. In order for Bremsstrahlung to be the source of the photons, the plasma must be less than 1/100 of a compton mean free path thick so that comptonization of the low energy photons of Bremsstrahlung[8] does not overwhelm the energetics of the emitted radiation. The comptonization of an already preformed, soft photon distribution from a low temperature black body (kT = 400 400 to 1000 eV) as suggested by Fenimore et al[5] allows for a significantly greater thickness of hot matter, τ of the order of 1 to 2 compton mean free paths. Even this larger thickness poses an extraordinary constraint on electron heating. In order to supply the thermal energy of the electrons necessary to compton heat the soft photon source and assuming further that the matter is distributed in a thickness corresponding to the radius of the neutron star, the heating of the electrons must take place recurrently in less than a microsecond. This short time precludes Coulomb collisions by many orders of magnitude (10^5, for $z = 1$ or by 100 for Fe) and so any classically proposed electron heating mechanism becomes unlikely.

Charge Separation and Photon Heating

If matter is being accreted onto a neutron star at close to the Eddington limit, the gravitational attraction of the ions must be balanced by a radiation stress that is exerted on the electrons by scattering processes. The electrons are then coupled to the ions by an electric field of charge separation. The actual charge separation needed to produce the balancing electric eld $E = m_p M_\Theta G/R^2 = 100$ eV/cm. The resulting electrostatic force on ıe electrons allows the ions to drag the electrons through the photon gas Compton scattering ensures a rapid thermodynamic equilibrium between elec rons and the photon gas, and the relative motion of the ions, relative to the photon gas, allows PdV work to be done on the photon gas. The photon gas has an energy density many times that of the particle thermal energy and it is the work done on the photon gas that absorbs the gravitational energy of accretion of the ions. To the extent that no new photons are produced within the time of compression of the photon gas, the mean energy of the photons will increase. This increase in energy of the photons or PdV heating of the photon gas when visage to be cyclic. Each time the photon gas is heated by one layer of in-falling matter, a fraction of these heated photons escapes and serves as the photon gas at a higher temperature and fewer photon for the succeeding collapsing layer. This process of cyclic PdV compression of a limited photon gas and subsequent diffusion and further heating by another layer is what we believe to be the origin of a hard spectrum of gamma bursts. A detailed modeling of this phenomenon is currently underway.

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